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<b>(71)(72) Applicant and Inventor:</b> FARBER, Mark, I. [US/US]; 347 Hotchkiss Road, Orange, CT 06477 (US).			
<b>(74) Agents:</b> CHAKANSKY, Michael, I. et al.; White & Case, 1155 Avenue of the Americas, New York, NY 10036 (US).			<b>Published</b> <i>With international search report.</i>

**(54) Title:** PROCESS AND APPARATUS FOR THE RECOVERY OF PRECIOUS METALS FROM SLAG, TAILINGS AND OTHER MATERIALS

**(57) Abstract**

The invention concerns methods and an apparatus for extracting precious metals and harmful matter from materials such as slag. The methods include freezing the pre-sized material; exposing it to ultraviolet and infrared radiation; roasting it in the presence of sodium borohydride, a metal salt, water and a combustible nitrogen material; and heating a mixture of the material and a fluxing agent comprising sodium cyanotrihydridoborate, and a mothering metal in a kiln.

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PROCESS AND APPARATUS FOR THE RECOVERY OF PRECIOUS  
METALS FROM SLAG, TAILINGS AND OTHER MATERIALS

Background of the Invention

The present invention concerns a process for  
5 the improved recovery of precious metals and other  
desired matter from slag, tailings and other source  
materials. The invention provides a recovery method  
which minimizes the use of harmful chemicals, in  
certain instances the invention may minimize the  
10 potential for harmful materials to escape into the  
environment during the roasting phase, and in certain  
instances the invention may make harmful components of  
the source material safer to handle.

The present invention is particularly  
15 advantageous in the economical removal of harmful  
matter and in economical extraction of desired matter,  
such as, precious metals, primarily gold, silver and  
platinum group metals, from source materials, such as,  
slag, tailings, etc. Prior art methods, to the extent  
20 applicable, are uneconomical or not as economical as  
the present invention. The mere existence of  
tremendous quantities of slag and decades old tailings  
containing significant quantities of precious metals  
locked within it, points to the unsolved problems  
25 those skilled in the art faced, at least in safely and  
economically recovering such metals.

Summary of the Invention

The invention provides several methods that  
can be used individually or in combination to recover  
30 precious metals.

In a specific embodiment of the invention, source materials containing the precious metals are formulated into a composition comprising the material, water and a combustible nitrogen material and the 5 composition is then roasted in the presence of sodium borohydride and a metal salt to a temperature from about 600°F to about 800°F. A suitable amount of a suitable fluxing agent comprising sodium cyanotrihydridoborate and a suitable mothering metal 10 are added to the roasted material and the entire mixture is heated in a rotary kiln to a temperature from about 1200°F to about 2000°F. The molten metal containing the precious metals is separated from the waste slag and recovered from the kiln.

15 In another embodiment of the invention, the source material containing the precious metals is ground or crushed to workable size and thoroughly frozen before being roasted. The source material may also be beneficially irradiated with electromagnetic 20 radiation, generally from just beyond either or both ends of the visual portion of the electromagnetic spectrum, during the freezing stage. Alternatively, the source material may be irradiated without freezing prior to roasting. Additionally, to enhance yield 25 combustible nitrogen materials may be added prior to further processing.

In another embodiment of the invention, the source material containing the precious metals with or 30 without prior processing is roasted in such a manner that substantially all matter which it is desired to recapture and which is ejected or volatilized from the source material being roasted will pass through an organic material preconditioned to readily attract and/or capture or adsorb desired ejected and

volatilized matter. For example, the organic material may be preconditioned to attract and capture precious metals, in which case, the organic material with its load of captured precious metals will be further 5 processed to recover the precious metals.

The invention also concerns a freezing and irradiation chamber, a roaster and the use of a sensitized organic material which are useful in practicing the methods of the invention.

10 The invention further concerns the removal of harmful matter from source materials containing them.

Detailed Description of the Invention

15 The process of the invention can be used on many materials containing precious metals or harmful substances. The methods of the invention are particularly advantageous in extracting harmful materials and precious metals, primarily gold, silver, and platinum group metals, from source materials, including, previously worked ores such as slag dumps, 20 flux piles, tailings, and slime dumps, or ores containing a low precious metal concentration; however, they may also be used on recently mined ores such as head ore and concentrates or placer deposits.

25 The source material, is first reduced to the proper processing size, that is, it is pre-sized, by, for example, grinding or crushing, in which case conventional ore processing methods using conventional machines such as a jaw crusher, rod mill or ball mill may be used. Generally, it is easier to process the 30 source material if its size is less than about 2 to 3 inches, and it is preferred that substantially all of the source material particles be about 1/8 to 3/8 of

an inch, as measured along its longest axis. The proper processing size of the particles depends upon the source material. For example, generally, it is preferred that the more dense materials should be 5 ground or crushed to a smaller particle size than less dense materials.

After the source material has been pre-sized, it is moistened with water. Enough water should be used so as to enable the source material to be 10 thoroughly moistened. The water used for moistening should be reasonably pure and should not contain significant amounts of any contaminants or additives. It is preferred that distilled, deionized water is used. In a preferred embodiment of the invention the 15 pre-sized source material is placed on a conveyor belt and is moistened by spraying with water. However, runoff water may be used after suitable recycling, for example to remove detrimental contaminants, if any.

The moistened source material is then frozen, 20 i.e., at some point in time every portion of the material should be at or lower than about 32°F. In a preferred embodiment of the invention the pre-sized material is transported on top of a conveyor belt into a freezing chamber and is transported by the conveyor 25 through the freezing chamber at a rate so as to insure that all the material has been completely frozen before it exits the chamber.

While the source material is being frozen it 30 may also be irradiated with electromagnetic radiation, generally from just beyond either or both ends of the visual portion of the electromagnetic spectrum, i.e., with ultraviolet and/or infrared radiation. Commercially available heat lamp bulbs (in the case of infrared radiation) or sun lamp bulbs (in the case of

ultraviolet radiation) can be used as the source of the radiation.

5        The need for irradiation, the type, intensity and duration of irradiation will depend upon the source material being irradiated.

10      Certain generalizations concerning irradiation have been found to enhance recovery of precious metals. Source material which contains more than a trace quantity of sulfides may beneficially be treated with ultraviolet ("UV") radiation. For the purposes of this portion of the process a trace quantity is defined as less than about one tenth of one percent by weight. If greater than trace quantities of cyanide are present in the source material, it may be 15      beneficially treated with infrared ("IR") radiation. If greater than trace quantities of arsenic and sulfides are present in the source material, it is generally not treated with UV or IR radiation during the freezing stage.

20      In a like manner, it is expected that the presence of other elements may suggest that the final yield of precious metals may be increased by the appropriate use of irradiation during the freezing stage. In the preferred embodiment of the invention 25      UV and IR radiation sources are located within the freezing chamber and are situated relative to the conveyor belt so that the material is subjected to the appropriate radiation as it progresses through the freezing chamber.

30      After freezing and before the material is thawed a combustible nitrogen composition is applied to the surface of the material. Any nitrogen based combustible material such as nitrogen based organic

fertilizer may be used. As long as a sufficient amount of the combustible nitrogen material is applied the amount of any excess is not critical since substantially all of the nitrogen material including 5 any excess will be burned in the subsequent roasting stage. A commercially available combustible nitrogen composition which has been found to be successfully utilized in the present invention is Malorganite® a fertilizer manufactured by Milwaukee Metro, of 10 Madison, Wisconsin.

In the preferred embodiment of the invention the combustible nitrogen material is distributed on the source material soon after the conveyor belt bearing the material emerges from the freezing 15 chamber. In this embodiment the combustible nitrogen material is contained in an application apparatus positioned above the conveyor belt and on the route between the freezing chamber and a roasting apparatus. If, prior to roasting, the source material appears to 20 be dry additional water should generally be added.

As is well known, the object of roasting is the expulsion of the sulphur, arsenic, antimony and other volatile substances existing in the source material, and the oxidation of the metals left behind. 25 To this end, the source material is heated in a furnace, through which a current of air is passed. Additionally, roasting has been used in the past as a preliminary to application of the well known cyanide process for the recovery of gold.

30 Roasting was used to reduce the presence of sulphur compounds in the source material. Basically, the cyanide process consists in attacking gold ores with dilute aqueous solutions containing less than one percent of alkaline cyanide, a slight excess of sodium

hydroxide or lime being added to ores rendered acid by the oxidation of pyrite, and then precipitating the precious metals with zinc. Certain, compounds, such as those containing sulfides or sulfates, referred to 5 as "cyanicides", are deleterious to the cyanide process, and are removed, e.g., by roasting, prior to the application of the cyanide process.

As is well known in the art, during the roasting process a significant amount of desired 10 matter, for example, precious metals, may be driven off into the atmosphere. While there are methods currently available to capture this escaping matter most are not conducive for the economical recovery of the desired matter. The inventor has found that by 15 roasting material in relatively close proximity to a sensitized organic material whereby substantially all of the desired escaping matter passes through the sensitized organic material a significant amount of desired matter may be captured by the sensitized 20 organic material and subsequently economically recovered.

Additionally, this process may be used to remove and capture or adsorb or otherwise render less harmful, specific harmful constituents of the source 25 material. For example, as referred to earlier, the roasting process has long been used to drive off sulphur compounds and arsenic compounds. However, as practiced in accordance with the present invention, the sulphur compounds and arsenic compounds which are 30 driven off the source material during the roasting stage may be captured by the sensitized organic material and thereby rendered less harmful to the environment. In a like manner, other harmful materials driven from the source material during

roasting may also be captured by the sensitized organic material.

The organic material which is to be sensitized can be any carbon based material such as coal, 5 charcoal, perlite, zeolite or vermiculite. The inventor has found Ammo-Carb® organic material supplied commercially by Astro Chemical, Co. of Springfield, Massachusetts, to be satisfactory. However, the sensitizing agents will generally vary 10 according to the material being roasted and the escaping matter which is to be captured or rendered less harmful.

In accordance with the present invention, certain generalizations concerning appropriate 15 sensitized organic materials to enhance recovery of precious metals can be made and successfully utilized. In order to sensitize the organic material it is first moisturized by applying reasonably pure and contaminant-free water. The moistened material is 20 then treated, by soaking or spraying with an aqueous acidic solution, no more than 30 per cent normal, e.g. acetic acid in water, i.e., vinegar, until the organic material is thoroughly covered with the acidic solution. A small amount of sodium borohydride should 25 generally also be added to the organic material. Finally to complete the sensitization an aqueous solution of a metal salt, e.g. an aqueous solution of silver nitrate may be applied to the organic material.

The sensitized organic material may be 30 recycled through the roaster until it becomes saturated with metal and can no longer economically capture or render less harmful desired matter escaping from the material being roasted on the first conveyor

5 belt. As the organic material is recycling through the roaster it should generally be periodically re-moistened, however, usually no other additional resensitizing is required. When the organic material is saturated it is processed in order to recover the desired matter, for example, any precious metals that escaped during the roasting process and which were captured by the sensitized organic material.

10 According to one embodiment of the present invention, the pre-processed material which also contains some water and the combustible nitrogen source is then roasted for about thirty to forty five minutes at a temperature from about 600°F. to about 15 800°F., and preferably 800°F, while in close proximity to the sensitized organic material.

20 The sensitized organic material may be placed directly over the material being processed, e.g., by resting on a second conveyor belt which is porous with respect to the ejecta or volatilized matter which is desired to pass through and about the sensitized organic material. However, it is necessary that the separation of the material being roasted from the sensitized organic material be such that the escaping matter will pass through the sensitized organic 25 material, but the material being roasted will not physically mix with the sensitized organic material.

30 In the preferred embodiment of the invention the material being processed progresses through the roaster on a first conveyor belt while at the same time the sensitized organic material is also passing on a second permeable conveyor belt positioned above and in relatively close proximity to the first conveyor. The material is roasted until it is

completely dry and all the nitrogen material is combusted.

Generally, the roasting process as described above will have the additional advantageous effect of 5 driving off harmful matter such as heavy metals, arsenic, sulfides, etc. from the material being processed. As noted earlier, by suitable adjustment to the sensitizing agents used for sensitizing the organic material such harmful matter which escapes 10 from the material will be captured or changed in form to a less harmful material.

For example, it is well known that chlorine in a gaseous form may be given off during the roasting process. Moreover, chlorine may also be set free by 15 the action of sulfuric anhydride on salt, while the presence of water vapor induces the formation of hydrochloric acid gas. However, as with the case of the sulphur compounds and arsenic compounds, the chlorine gas and hydrochloric acid gas, driven off the 20 source material during the roasting stage, pass through and about the sensitized organic material. The chloride gas and hydrochloric acid gases may then react with the sensitized organic material and may thereby be reduced for example to sodium chloride and 25 sodium sulphate.

According to one embodiment of the present invention, after the sensitized organic material leaves the roaster it is analyzed to ascertain whether or not it is saturated with metals. By saturated the 30 inventor means with respect to this process that about one percent or more of the surface area of the sensitized organic material is covered with metallic matter. If it is saturated the organic matter is burned off leaving metal dust. If it is not saturated

it is recycled through the roasting stage after first moisturizing again with water.

According to one embodiment of the invention, after the material being processed leaves the roaster 5 suitable fluxing and mothering agents are then added to the roasted material. The amount and identity of the fluxing and mothering agents to be added will in a large part be determined by the composition of the material being processed and the matter desired to be 10 recovered.

The identity and methods and conditions of use of such fluxing agents, for example, oxidants (such as, the Oxone® oxidant manufactured by Dow Chemical Company), fluorides (such as the Flourspar® calcium 15 fluoride composition manufactured by DuPont), chlorides, nitrogen compounds (such as the Nitre® nitrogen compound manufactured by Seder Chemical Co., of Vicksburg, Mississippi), sodium compounds, etc., such as, calcium fluoride, potassium nitrate, soda 20 ash, boric acid, sodium cyanotrihydridoborate are well known to those skilled in the art. The use of sodium cyanotrihydridoborate is not similar to the use of cyanide in the cyanide process referred to above. The present invention does not use an aqueous solution of 25 a cyanide compound, moreover, the present invention uses an insignificant quantity of cyanide compound as compared to the quantity necessary for the cyanide process.

Generally, soda ash and boric acid should 30 always be used. Moreover, if the source material has high amounts of arsenic (e.g., greater than about ten parts per million), then the addition of a small amount of sodium cyanotrihydridoborate (e.g., about

one ounce per ton) will generally enhance the final yield.

Other characteristics of the source material, e.g. the pH of an aqueous solution of source material 5 or the viscosity of a hot melt of the material, will generally suggest additions to the quantity and/or type of materials used above as fluxing agents. For example, the source material may be pulverized, water added and the pH of the resulting aqueous solution 10 ascertained. According to the present invention, an acidic pH suggests that additional basic compounds, e.g., soda ash, be added, while an alkaline pH suggests that additional acidic compounds, e.g., boric acid, be added. If the pH is neutral, then no 15 additional acidic or basic compounds need be added, however, as described earlier an initial quantity of both boric acid and soda ash are generally always used in the fluxing media.

Additionally, it is desired that the material 20 for post-roasting processing be capable of flowing easily under the process conditions. If the material being processed is very viscous during a test melt, the addition of clays, such as bentonite or dolomite, may decrease the viscosity and thereby enhance the 25 final yield.

Finally, an appropriate metal mothering agent should be added to the mixture of fluxing agents and material. The mothering agents to be used will depend upon the material being processed and the matter for 30 which recovery is to be maximized. For example, if the recovery of gold is to be enhanced, copper oxide may be beneficially added to the mixture as a mothering agent. It has been found that the addition of about five percent by weight of copper oxide and

silver oxide will enhance the recovery of gold up until the point is reached wherein the gold content of the dore' exceeds about forty percent by weight.

Other mothering agents include tin and lead oxide. In 5 one embodiment of the invention the mothering metal comprises 90 lbs. of copper oxide and 10 lbs. of silver oxide. The mixture of the material, flux and mothering agent is then heated with agitation, for example in a rotary kiln.

10 The mixture is heated to a temperature from about 1000°F. to about 3000°F., preferably about 2000°F, and the resulting metal product containing precious metals is removed. In the preferred embodiment of the invention a rotary kiln is used and 15 the slag and metal shot product are removed from the kiln either continuously or periodically.

The metal product or shot is further refined to isolate the non-platinous precious metals that are to be recovered. According to one embodiment of the 20 present invention, this may be accomplished by analyzing the metal shot for precious metal content and based on the analysis and in a recycling process adding more mother materials and then heating the mixture with agitation in the same manner as done 25 initially, or recovering the precious metals from the shot.

A point is reached where recycling after the addition of mothering agents will not increase and may in fact lower the yield of precious metals. It is at 30 this point that recycling should be stopped and the precious metals recovered. For example, the inventor has found that for one starting material, when the metal shot reaches about forty (40) percent gold in

content, further recycling actually reduces the final yield.

5 The fluxed material poured from the kiln, i.e., the slag, is pulverized, for example in a crusher, and then analyzed. Initially, the pulverized material is mixed with water and the resulting aqueous solution is analyzed and the pH determined. If the pH is not neutral, materials tending to drive the solution to a neutral pH should generally be added.

10 The amount of platinum group metals present in the slag is also initially determined, e.g., by atomic absorption or fire assay. If the level of platinum group metals present is below economical recovery amounts the slag may be used for other purposes. For 15 example, the slag may be poured into bricks and used for construction purposes, or used as a concrete or asphalt filler, or added to materials used for sandblasting, or used for ballast on ships, etc. However, if platinum group metals are present in 20 economical recovery amounts the material will generally be further refined to recover these metals. Further, a high percentage of platinum group metals suggests that additional soda ash and/or a tin-lead compound and/or other mothering agents may be 25 beneficially added.

30 The next step is to heat and mix the slag, pH altering agents and the mothering agents together. Generally, the pH altering agents and the mother agents remain the same for an entire lot of similar source material.

The mixture should be heated at a temperature greater than about 2000°F and less than about 3500°F, preferably between about 2800°F and about 3000°F. The

slag is poured off, e.g., into bricks, and the platinum group metals are recovered from the metal shot.

The slag produced by this invention, as noted above, may be used in the production of construction 5 materials and other products such as bricks, etc.

## Example.

In the following example a 100 pound sample of slag source material was processed according to an embodiment of the present invention. The slag was 5 processed to enhance the recovery of silver and gold. A fire assay was performed on the slag before and after the processing.

The slag was preconditioned. It was ground to approximately pea size particles, placed into five 10 separate doubled-up plastic garbage bags and moisturized with water. The bags were then placed in a standard upright freezer overnight. The bags were emptied into a crucible, about a cup of Malorganite® 15 nitrogen composition was added to the slag and the contents of the crucible mixed.

The organic material was sensitized. In a mixing vessel, to about forty (40) pounds of Ammo Carb® organic material, enough vinegar was poured in so as to completely cover the Ammo Carb® organic 20 material. Next, about a gram of sodium borohydride was added, the contents of the vessel mixed and the excess liquid poured off. Elsewhere, about 6 to 12 pieces of unexposed X-ray film were dipped in a five gallon container, containing about two gallons of 25 Kodak brand photographic fixer, to obtain the silver salt, e.g., silver nitrate. After dipping, the liquid solution from the five gallon container was then poured into the vessel containing the Ammo Carb® organic material, etc., and the contents mixed. 30 Finally, the liquid from the vessel was poured off, and the now sensitized organic material was placed in a heat resistant porous bag, manufactured by Joe Slater, Inc. of Teterboro, New Jersey.

The roasting step. The porous bag containing the sensitized organic material was placed on top of the preconditioned slag in the crucible. The crucible was then heated in a furnace at a temperature of about 5 800°F for approximately 45 minutes. The bag of sensitized organic material was removed and separately tested positive for the presence of gold. The roasted material was poured off and allowed to cool.

Preparing the fluxing agent. The following 10 ingredients were mixed together to form the fluxing agent: 2 pounds of soda ash; 1 1/2 pounds of boric acid, a teaspoon of Flourspar® calcium fluoride composition; and about 1/4 gram of sodium cyanotrihydridoborate.

15 The fluxing agent was then mixed with the roasted material providing a roasting material/fluxing agent mixture.

The mothering agent used was about 10 pounds of copper.

20 About 1/4 of the roasted material/fluxing agent mixture was then mixed with about 1/4 of the mothering agent in a smaller crucible. The smaller crucible was heated at about 2100°F until the contents were molten. The molten contents were poured into a 25 mold and allowed to cool. The mold was tipped over causing the slag and "metal" portion to separate. The metal portion was then placed back in the smaller crucible, another 1/4 of the roasted material/fluxing agent mixture and another 1/4 of the mothering metal 30 were added. Again the crucible was heated at 2100°F until the contents were molten. This cycle was continued until all of the roasted material/fluxing

agent mixture had been heated with the mothering agent.

The source material and the last metal portion were then fire assayed. The results were as follows:

5	<u>Material</u>	<u>Au (oz/ton)</u>	<u>Ag (oz/ton)</u>
	Source Material	0.002	0.17
	Last Metal Portion	1.383	9.36

10 This invention, its preferred embodiments and several examples have been described in detail. It will be appreciated that those skilled in the art, upon consideration of this disclosure, may make modifications and improvements within the scope of the invention as defined by the claims.

## CLAIMS:

1. A process for the recovery of desired metals from source materials containing the desired metals comprising:

5 a. roasting a composition comprising the source material, water and a combustible nitrogen material in the presence of sodium borohydride, a metal salt and an organic material to a temperature from about 600°F to about 800°F so as to obtain a

10 roasted material;

b. adding a suitable amount of a suitable fluxing agent and a suitable mothering metal to the roasted material and heating the material in a kiln to a temperature from about 1200°F to about 2000°F; and

15 c. separating and recovering the molten metal containing the desired metals from the kiln.

2. A process as in claim 1 wherein the suitable fluxing agent comprises a sodium borohydride composition.

20 3. A process for the recovery of desired metals from materials containing the desired metals comprising:

a. crushing or grinding the source material and moistening the material with water;

25 b. lowering the temperature of the source material to a temperature of less than about 32°F;

c. roasting the source material;

d. adding a suitable amount of a suitable fluxing agent and a suitable mothering metal to the

30 material and heating the material in a kiln to a temperature from about 1200°F to about 2000°F; and

e. separating and recovering the molten metal containing the desired metals from the kiln.

4. A process for the recovery of precious metals from source material containing the precious metals comprising:

- a. crushing or grinding the source
- 5 material and moistening the material with water;
- b. lowering the temperature of the source material to a temperature of less than about 32°F;
- c. exposing the source material to electromagnetic radiation;
- 10 d. roasting the source material;
- e. adding a suitable amount of a suitable fluxing agent and a suitable mothering metal to the roasted source material and heating the material in a kiln to a temperature from about 1200°F to about
- 15 2000°F;
- f. separating and recovering the molten metal containing the precious metals from the kiln; and
- 20 g. separating and recovering slag from the kiln.

5. A process as in claim 4 wherein precious metals are separated and recovered from the slag from the kiln.

6. A process as in claim 5 wherein the precious metals are separated and recovered from the slag by the method comprising:

- a. pulverizing the slag;
- b. adding suitable pH altering agents and suitable mothering agents;
- 30 c. mixing the pulverized slag and the agents together;
- d. heating the mixture to between about 2000°F and 3000°F; and

e. pouring off the molten metal for further precious metal separation and recovery.

7. A process as in claim 3 wherein while the temperature of the material is being lowered, the  
5 material is exposed to electromagnetic radiation.

8. A process as in claim 4 or 7 wherein the electromagnetic radiation is from the infrared and/or ultraviolet portions of the electromagnetic spectrum.

9. A process as in claim 8 wherein the  
10 source of the infrared radiation is commercially available heat lamp bulbs.

10. A process as in claim 8 wherein the source of the ultraviolet radiation is commercially available sun lamp bulbs.

15 11. A process as in claim 3 or 4 wherein before the source material is roasted it is combined with a combustible nitrogen material and then roasted in the presence of a sensitized organic material at a temperature from about 600°F to about 800°F.

20 12. An apparatus useful for treating source materials containing desired metals prior to the recovery of the desired metals which comprises a freezing chamber and suitable sources of electromagnetic radiation.

25 13. An apparatus as in claim 12 wherein an ultraviolet light source is provided.

14. An apparatus as in claim 12 wherein an infrared light source is provided.

15. A process for the recovery of desired matter from source materials containing the desired matter, comprising:

- a. preparing the source materials for 5 roasting;
- b. mixing a combustible nitrogen material with the prepared source materials;
- c. preconditioning an organic material so as to become a sensitized organic material which will 10 attract and/or capture desired matter which is ejected or volatilized from the source material during roasting;
- d. roasting the mixture at a temperature from about 600°F to about 800°F, in the presence of 15 the sensitized organic material, in such a manner that substantially all desired matter which leaves the mixture will pass through and/or about the sensitized organic material; and
- e. processing the roasted mixture to 20 recover any precious metals.

16. A process as in claim 15 wherein the source material is prepared for roasting by a method comprising:

- a. pulverizing the source material to 25 reduce the particles constituting such material to a suitable processing size;
- b. moisturizing the pulverized particles with water; and
- c. then lowering the temperature of the 30 moisturized particles to less than about 32°F.

17. A process as in claim 16 wherein the source material is further prepared for roasting by irradiating the moisturized particles with electromagnetic radiation during the temperature 35 lowering process.

18. A process as in claim 17 wherein the electromagnetic radiation is from the infrared and/or ultraviolet portions of the electromagnetic spectrum.

19. A process as in claim 16 wherein the 5 suitable processing size is when substantially all of the source material particles are about 1/8 to 3/8 of an inch, as measured along the particles longest axis.

20. A process as in claim 15 wherein the 10 organic material is sensitized by the addition of suitable sensitizing agents to the organic material, wherein the sensitizing method comprises:

- a. moisturizing the organic material by applying water;
- b. applying a suitable aqueous acidic 15 solution;
- c. applying a small amount of sodium borohydride; and
- d. applying a suitable aqueous solution of a metal salt.

21. A process as in claim 20 wherein the 20 suitable aqueous acidic solution is vinegar.

22. A process as in claim 20 wherein the suitable metal salt is silver nitrate.

23. A process as in claim 15 wherein the 25 matter which is ejected or volatilized from the mixture being roasted and which passes through the sensitized organic material is a harmful material which may be dangerous to dispose of or handle and which by passage through and about the sensitized 30 organic material has been captured and/or changed by the sensitized organic material so that the captured

and/or changed harmful material can be less dangerously disposed of or handled.

24. A process as in claim 15 wherein the sensitized organic material is processed after 5 roasting to recover precious metals which had been ejected or volatilized from the source material during roasting.

25. A process for the recovery of precious metals from a source material containing the precious 10 metals comprising:

a. preconditioning the source material by: ensuring that the particles constituting such material are of a suitable processing size, moisturizing the particles with water, lowering the 15 temperature of the moisturized particles to cool them to less than about 32°F while irradiating the moisturized particles with electromagnetic radiation;

b. sensitizing an organic material by mixing it with: reasonably pure and contaminant-free 20 water, an aqueous acidic solution, a small amount of sodium borohydride, and an aqueous solution of a metal salt;

c. roasting a mixture of the 25 preconditioned source material and a combustible nitrogen material at a temperature from about 600°F to about 800°F in such a manner that substantially all desired matter ejected or volatilized from the preconditioned source material will pass through and/or about the sensitized organic material;

d. adding a suitable amount of a suitable 30 fluxing agent comprising sodium cyanotrihydorate and a suitable mothering metal to the roasted source material and heating the material in a kiln to a temperature from about 1200°F to about 2000°F;

- e. separating and recovering precious metals from the sensitized organic material after roasting;
- f. separating and recovering the molten metal containing the precious metals from the kiln; and
- 5 g. separating and recovering the slag containing precious metals from the kiln, and then pulverizing the slag, adding suitable acidic and/or 10 basic materials and suitable mothering agents, mixing the pulverized slag and the agents together, heating the mixture to between about 2000°F and 3000°F, and pouring off the molten metal for further precious metal separation and recovery.

# INTERNATIONAL SEARCH REPORT

International Application No. PCT/US90/02545

## I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) <sup>6</sup>

According to International Patent Classification (IPC) or to both National Classification and IPC  
 IPC (5): C22B 11/00 BOIJ 19/08  
 U.S.Cl.: 75/10.13, 414, 416 422/186, 186.3

## II. FIELDS SEARCHED

Minimum Documentation Searched <sup>7</sup>

Classification System	Classification Symbols
U.S.	75/10.13, 10.29, 414, 416, 631, 632, 633, 634, 637 422/186, 186.3 62/264

Documentation Searched other than Minimum Documentation  
to the Extent that such Documents are Included in the Fields Searched <sup>8</sup>

## III. DOCUMENTS CONSIDERED TO BE RELEVANT <sup>9</sup>

Category <sup>10</sup>	Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>
A	U.S., A, 4,608,083 (HOLMSTRON et al.) 26 August 1986	1, 2, 3, 15, 16 and 19 to 24
A	U.S., A, 4,695,317 (KIMURA et al.) 22 September 1987	1, 2, 3, 15, 16 and 19 to 24
A	U.S., A, 4,814,003 (BERGNER) 21 March 1989	1 to 11 and 15 to 25
A	Japan A 1,063,092 09 March 1989	4 to 11, 17, 18 and 25
X P	U.S., A, 4,867,052 (CIPELLETTI) 19 September 1989	12 and 13
X	Japan, A, 1,006,684 11 January 1989	12 and 14

\* Special categories of cited documents: <sup>10</sup>

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

## IV. CERTIFICATION

Date of the Actual Completion of the International Search

Date of Mailing of this International Search Report

29 June 1990

International Searching Authority

ISA/US

Signature of Authorized Officer

*Melvyn J. Andrews*  
Melvyn J. Andrews